

**Presentation for  
First Quarterly Review of the  
NGLT Vehicle Systems Research & Technology Project  
Hampton, VA  
March 24-28, 2003**

**Advanced Control Surface Seal Development at NASA GRC  
for Future Space Launch Vehicles**

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NASA's Glenn Research Center (GRC) is developing advanced control surface seal technologies for future space launch vehicles as part of the Next Generation Launch Technology project (NGLT). New resilient seal designs are currently being fabricated and high temperature seal preloading devices are being developed as a means of improving seal resiliency. GRC has designed several new test rigs to simulate the temperatures, pressures, and scrubbing conditions that seals would have to endure during service. A hot compression test rig and hot scrub test rig have been developed to perform tests at temperatures up to 3000°F. Another new test rig allows simultaneous seal flow and scrub tests at room temperature to evaluate changes in seal performance with scrubbing. These test rigs will be used to evaluate the new seal designs. The group is also performing tests on advanced TPS seal concepts for Boeing using these new test facilities.

# **Advanced Control Surface Seal Development at NASA GRC for Future Space Launch Vehicles**

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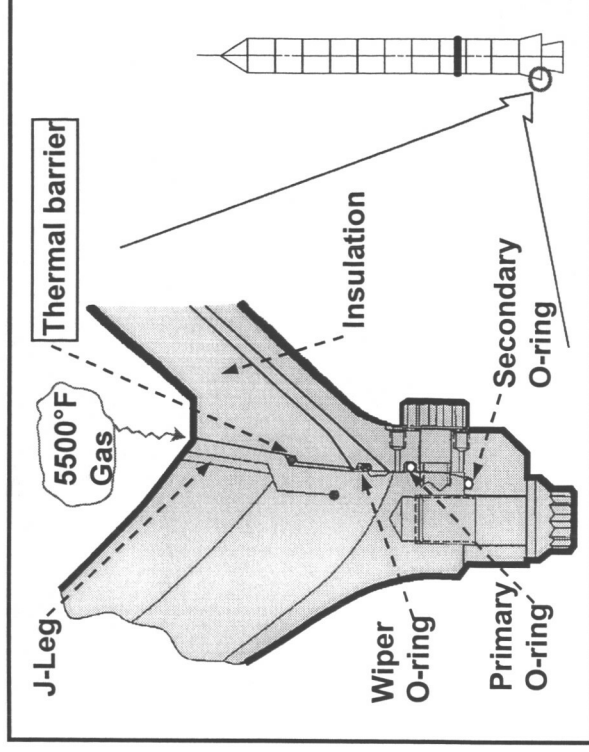
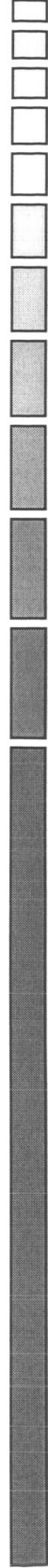
# Background & History

- NASA GRC recognized as Center of Excellence for high temperature structural seal development:

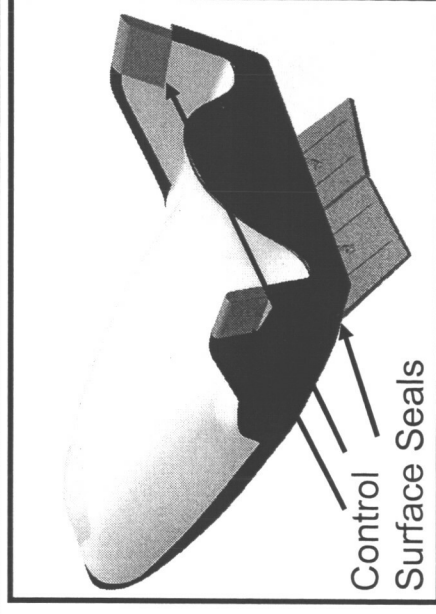
- Led seal development effort for NASP (National Aero-Space Plane) project (1986-1992) including airframe and propulsion system seals
- Thiokol/NASA Marshall selected GRC carbon fiber rope thermal barrier for re-design of nozzle joints in Space Shuttle RSRM's (1998-2003)
- At request of NASA JSC, evaluated control surface seals (e.g., rudder/fin seals) for X-38 / Crew Return Vehicle (1999-2002)
  - Seals survived re-entry level heating
  - Identified loss of seal resiliency that forced re-design of rub surface
- Initial request to assist in seal improvements for Shuttle return to flight (2003)



NASA Glenn Research Center



Thermal Barrier for Shuttle RSRM



X-38 Seals

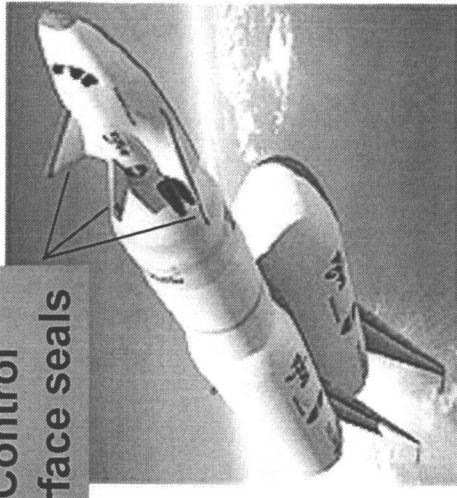
# Control Surface Seal Development: Motivation and Objectives



- **Why is advanced seal development important?**

- Seal technology recognized as critical in meeting goals for next generation launch vehicle system
- Value Stream process identified Airframe and Control Surface Seals as **Priority 1 Shortfall** (Identifier 3.08-Mi2.2.6-6) for Vision Vehicles
- No control surface seals have been demonstrated to withstand required seal temperatures (2000-2500°F) and remain resilient for multiple temperature exposures while enduring scrubbing over rough sealing surfaces

Control surface seals

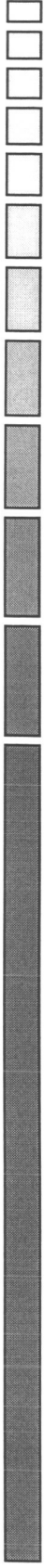


- **NASA GRC Seal Team leading NGLT VSR&T task to develop advanced control surface seals**

**Goal:** Develop long-life, high temperature control surface seals for next generation airbreathing or rocket-based vehicle systems and demonstrate through laboratory tests.

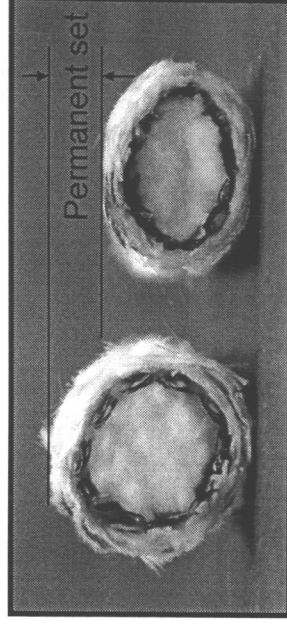
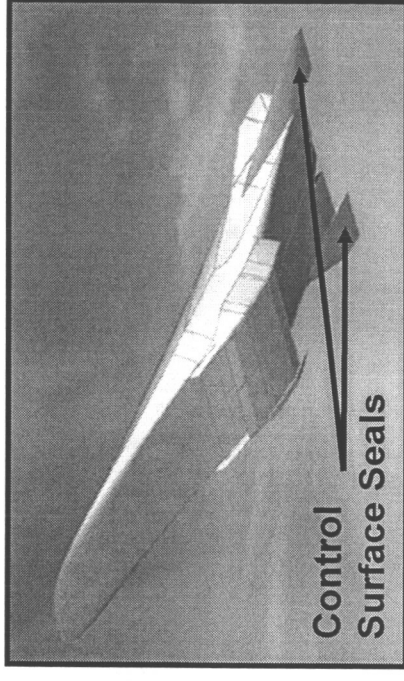


# Control Surface Seal Challenges and Requirements



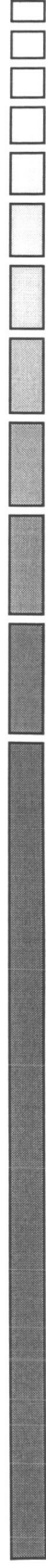
- **Seal requirements:**

- Limit hot gas ingestion and leakage
- Limit transfer of heat to underlying low-temperature structures
- Withstand temperatures as high as 2000-2500°F for multiple heating cycles
- Maintain resiliency (spring back) for multiple heating cycles
- Limit loads against opposing sealing surfaces
- Resist scrubbing damage against opposing sealing surfaces
- Perform all functions for 10X increase in service life over current Shuttle seals



**Challenge:** Design hot, resilient seals that meet mission reusability requirements

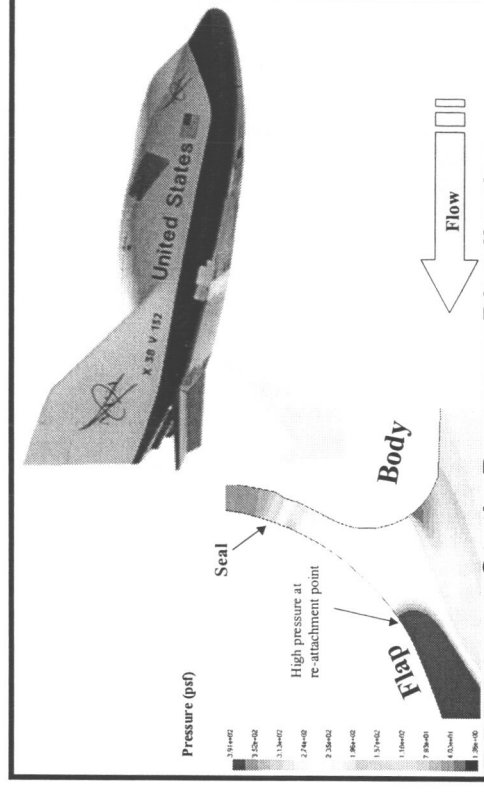
# Control Surface Seal Development Plans



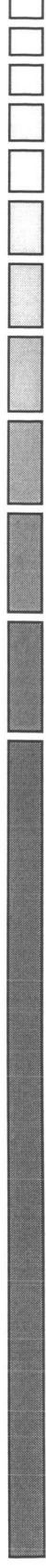
- Design advanced seal concepts to meet challenging requirements
- Develop high temperature seal preloading devices (e.g., springs) as potential means of improving seal resiliency
- Evaluate seals and preloaders in new NASA GRC test rigs under representative conditions:
  - Hot compression rig (stroke rate: as low as 0.001 in/sec at 3000°F)
  - Hot scrub rig (stroke rate: up to 8 in/sec at 3000°F)
  - Cold flow & scrub test rig ( $\Delta P$ : 0 to 2 psid)

## • Environmental exposure tests will be performed in other facilities:

- Arc jet tests (NASA Ames Panel Test Facility)
- Thermal acoustic tests (NASA LaRC or WPAFB)
- Aero-thermal-structural analyses of seals using tightly integrated CFD-FEA analysis tools



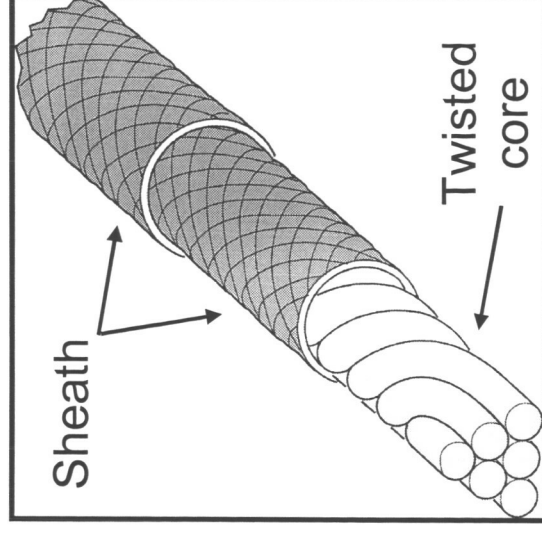
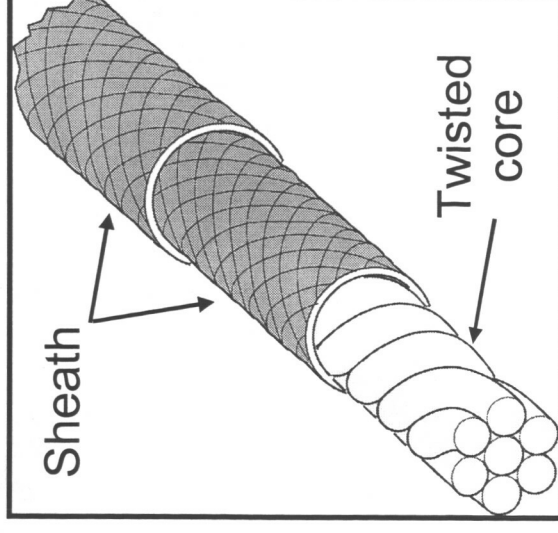
# Advanced Control Surface Seal Designs



- **Selected new advanced seal designs to purchase and test this year**

- Improvements to outer sheath
  - Ceramic sheath for high temperature applications with limited scrubbing
  - Advanced high temperature metallic sheath for better abrasion resistance
- Modifications to core structure
  - Twisted core of smaller braided rope seals to improve resiliency
  - Structured core provides integrity and helps overcome problem of Saffil core being ejected during flight
- Improvements to spring tube design
  - Replacing Inconel X-750 with materials that have better strength and creep resistance at high temperatures
  - Considering changes to spring tube knit pattern

- **Vendors currently providing quotes**

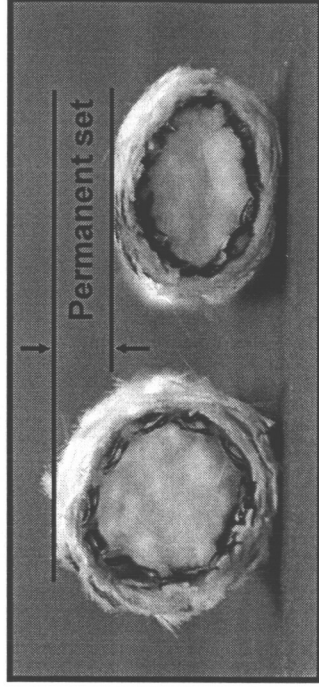


# Development of High Temperature Seal Preloading Devices

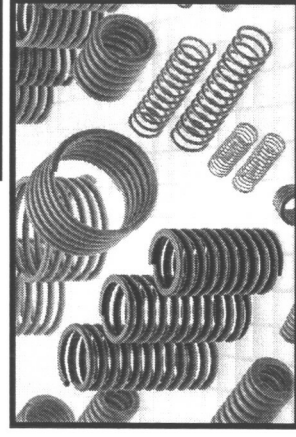
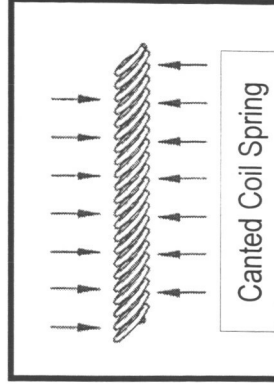
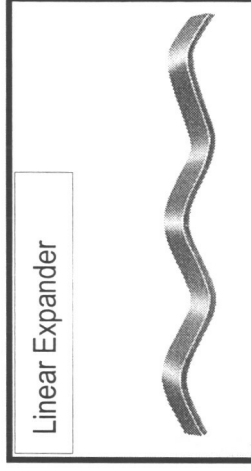


- **Competitive procurement to develop high temperature seal preloading devices in FY03**

- Solicitation closed on March 21
- Currently evaluating proposals
- Plan to select vendor and award contract in early April
- FY03 funding for this effort: ~\$100K
- Contract will have option package that could be awarded for FY04 based on performance



**Seals Before and After 1900°F Exposure  
Showing Loss of Seal Resiliency**

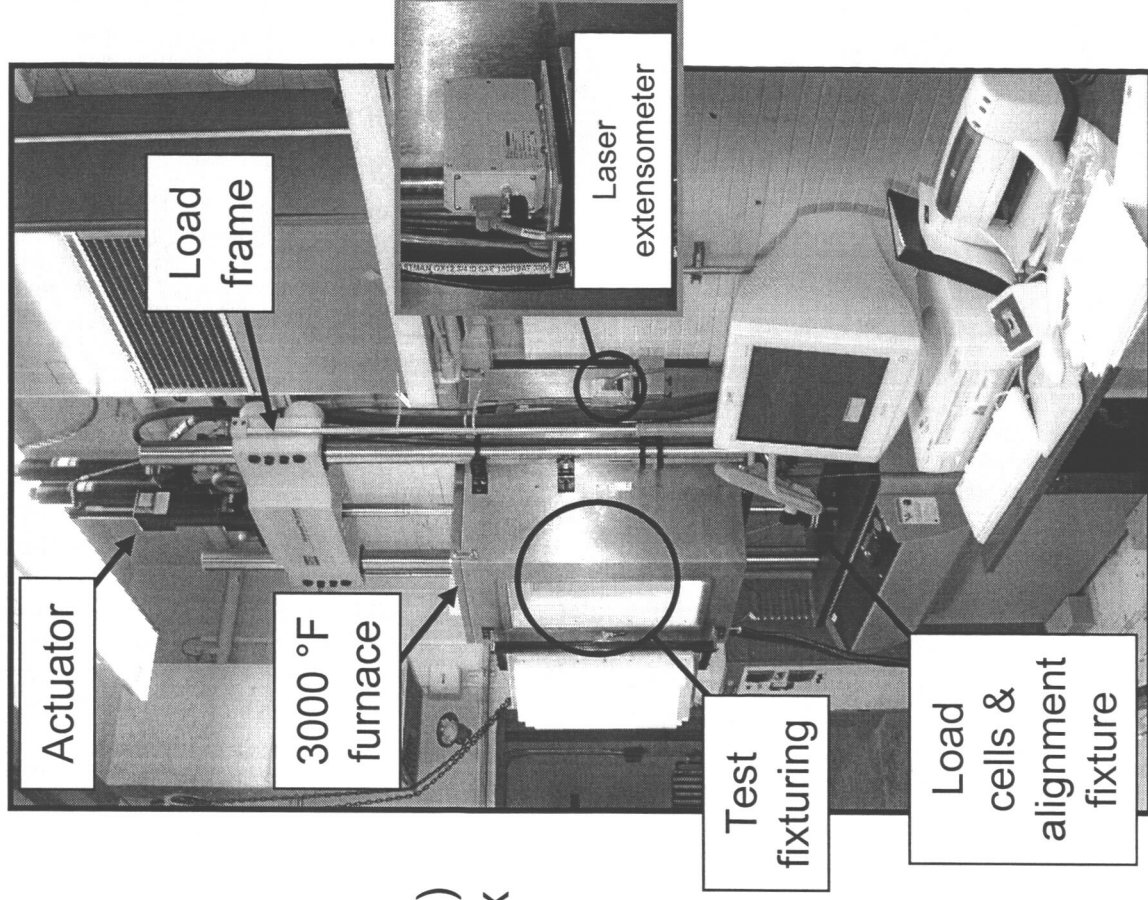


**Candidate Seal Preloading  
Devices**

# Hot Compression / Hot Scrub Rig

## System Components

- MTS Servohydraulic Load Frame
  - Actuator: 3300 lb, 6 in. stroke
  - Load cells: 500 lb, 3300 lb
  - Dual servovalves: 1 gpm, 15 gpm
- ATS Custom Box Air Furnace
  - Temperatures up to 3000°F (14.5 kW)
  - Large working volume (9" W x 14" D x 18" H)
  - Front and back loading doors & top port
- Beta LaserMike Intelliscan 50 Extensometer
  - Non-contact Class II laser extensometer
  - 0 to 2 in. measurement range
  - $\pm 0.25$  mil accuracy



# Hot Compression Rig Details

## Purpose

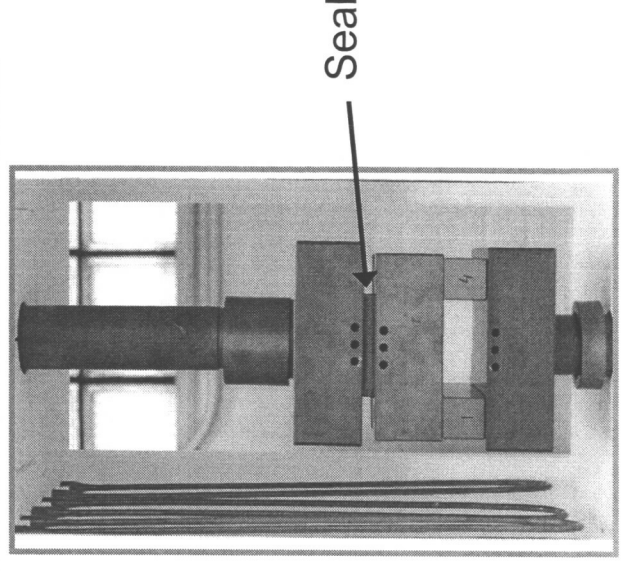
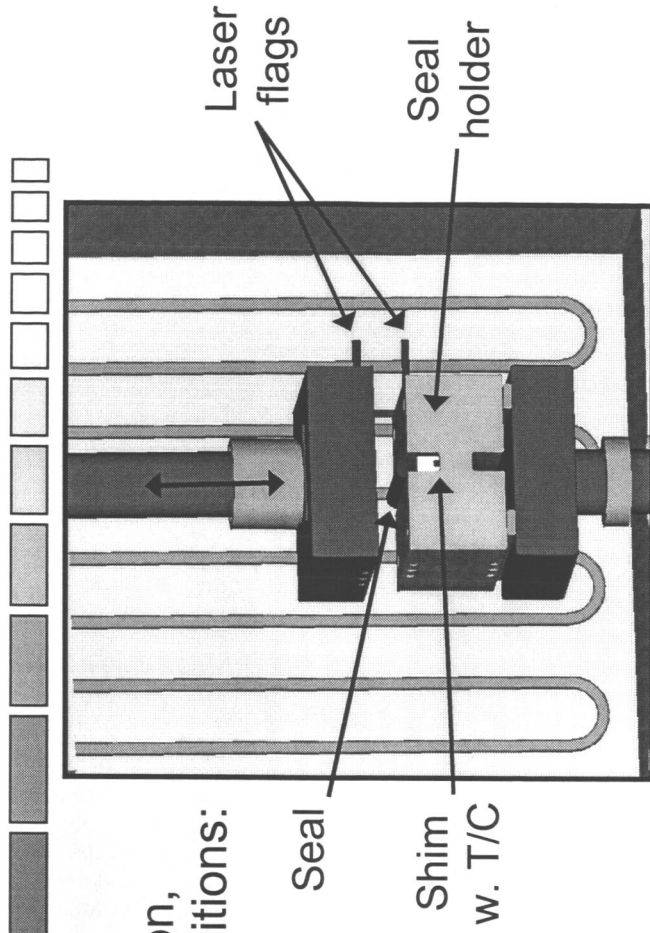
- Measure seal load vs. linear compression, preload, & stiffness for various test conditions:
  - Temperature
  - Compression level
  - Loading rate
  - Load cycling
  - Stress relaxation

## Capabilities

- Temperatures up to 3000°F (1650°C)
- Loads up to 3300 lb
- Stroke rates: 0.001 to 8.0 in/s
- Seal: lengths up to 4 in.; diameters up to 2 in.
- Variety of loading waveforms
  - Cycling (sine wave, sawtooth, user-defined profiles)
  - Stress relaxation

## Status

- Operational



# Hot Scrub Rig Details

## Purpose

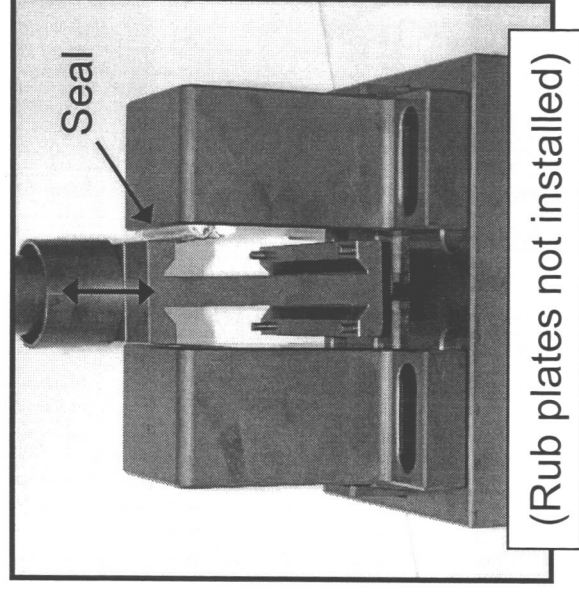
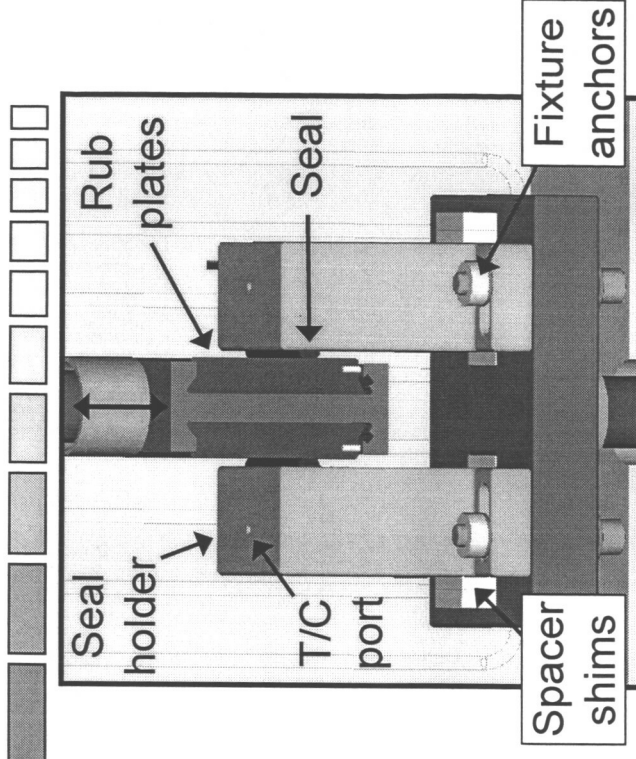
- Measure wear rates and frictional loads for various test conditions:
  - Temperature
  - Compression level
  - Stroke rate and number of cycles
  - Rub surface conditions (material, roughness, surface profile)
  - Scrub direction

## Capabilities

- Temperatures up to 3000°F (1650°C)
- Loads up to 3300 lbs
- 3 in. stroke at rates from 0.001 to 8.0 in/s
- Seal: lengths up to 4 in.; diameters up to 2 in.
- Gaps: 0 to 0.625 in.
- Variety of cyclic loading waveforms (sine wave, sawtooth, user-defined profiles)
- Pre- & post-scrub flow testing

## Status

- Checking out test fixturing; nearly operational



# Hot Scrub Rig Details: Pre- and Post-Scrub Flow Testing



## Purpose

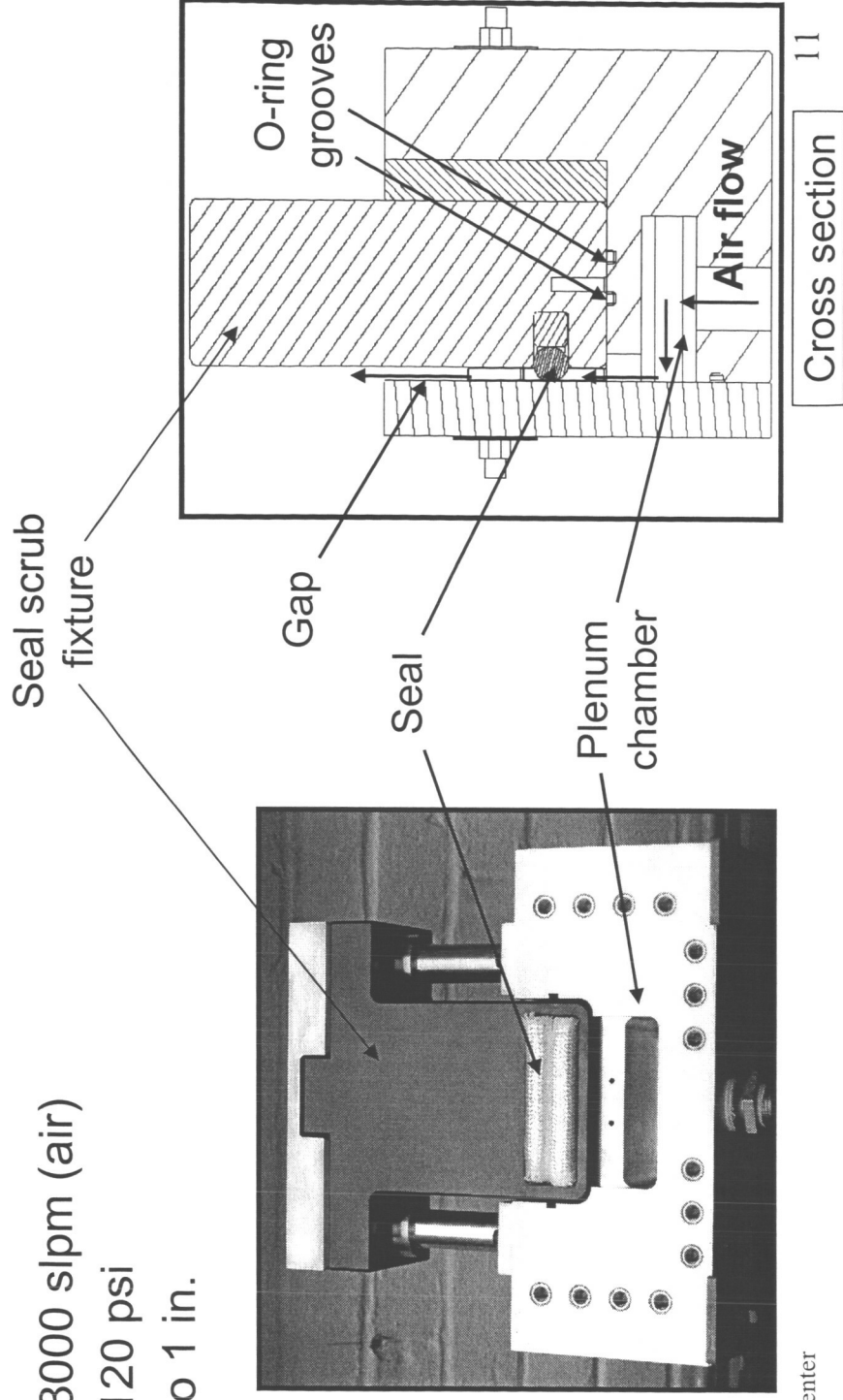
- Permits pre- and post-scrub flow evaluation of seals at room temperature
  - Flow testing at 2000+ °F prohibitively expensive and complicated
  - Design minimizes seal damage due to handling (seal undisturbed between scrub test and flow test)

## Capabilities

- Flow rates: 0 to 3000 slpm (air)
- Pressures: 0 to 120 psi
- Gap settings: 0 to 1 in.

## Status

- Operational



# Cold Flow & Scrub Test Rig

## Purpose

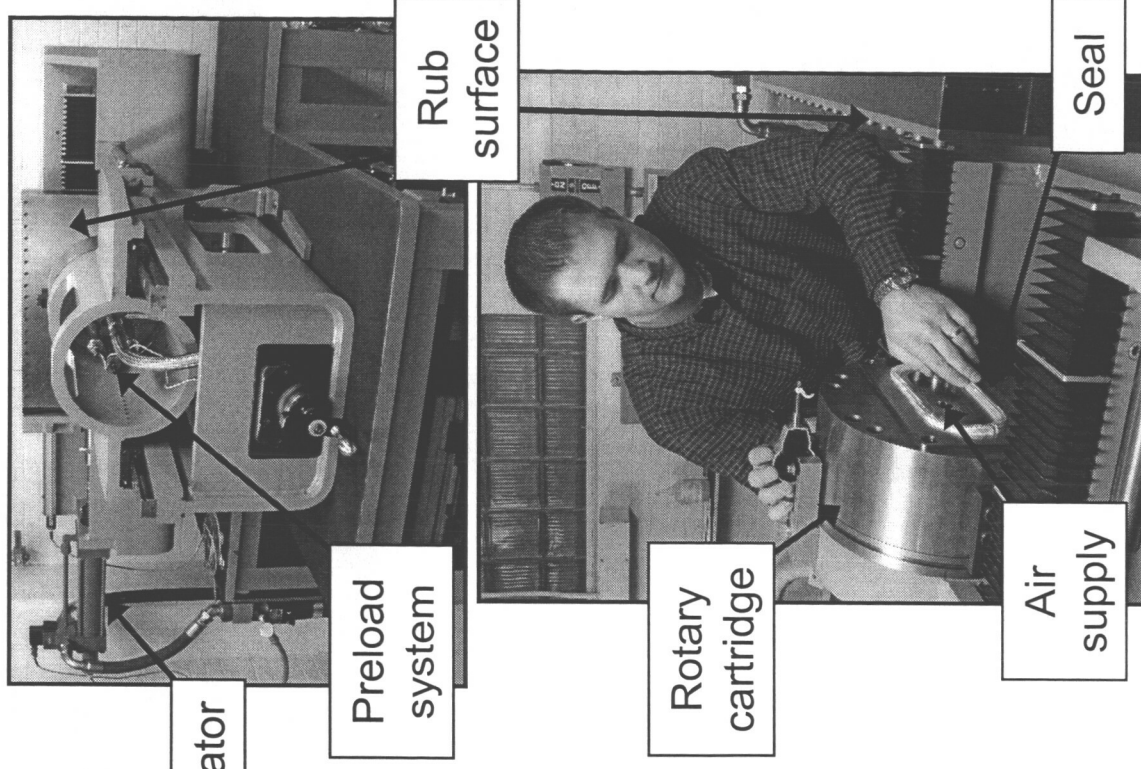
- Perform combined flow and scrub tests at room temperature for various test conditions:
  - Scrub/cycle damage
  - Compression level
  - Gap size

## Capabilities

- Variety of seal configurations
- Seal lengths 8 in. or longer
- Scrub rates up to 12 in/s for 12-in. stroke
- Frictional scrub loads up to 10 kip
- Active (pneumatic) or passive (Belleville washers) seal preload system
- Multiple scrub directions (cartridge can be rotated)
- Variety of rub surface conditions (material, surface roughness, surface profile)
- Flow rates: 0 to 3000 slpm (air)
- Pressures range: 0 to 120 psi

## Status

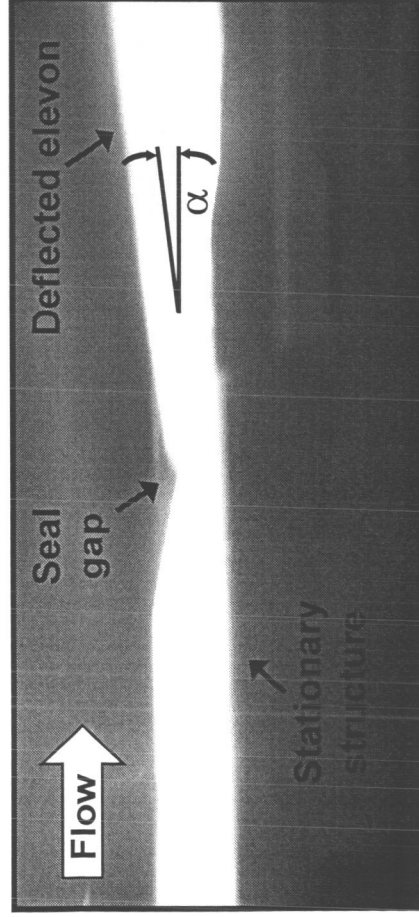
- Completing installation and checkout



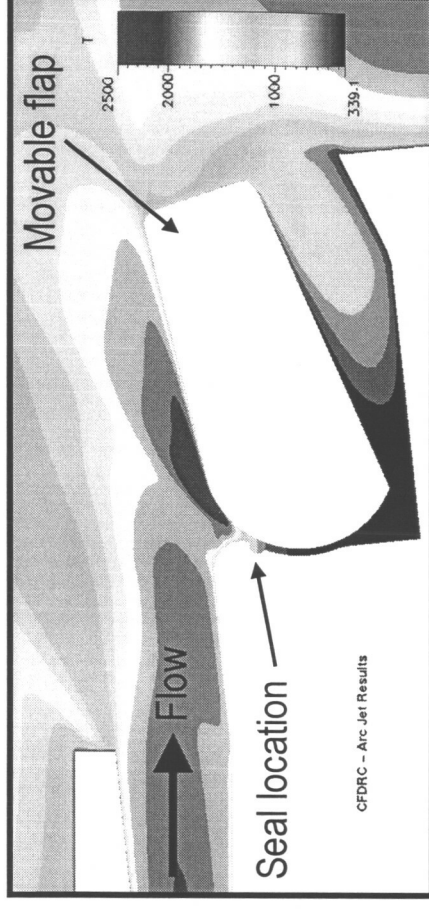
# Arc Jet Testing of Baseline Control Surface Seal



- Examined seal performance under re-entry level heating conditions both experimentally and numerically
- CFD Research Corp. completed aero-thermal-structural analyses of gap seals tested in NASA Ames arc jet facility



Side view of test article during arc jet test



Temperature predictions by  
CFD RC arc model (in K)

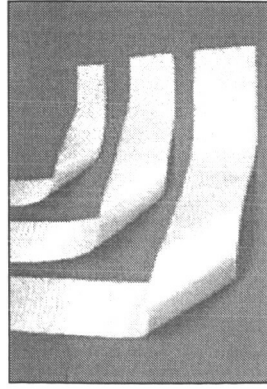
**Temperatures and pressures predicted near porous seal corresponded well with actual test data**



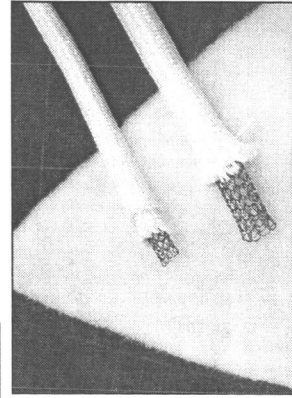
# Testing of Boeing TPS Seals



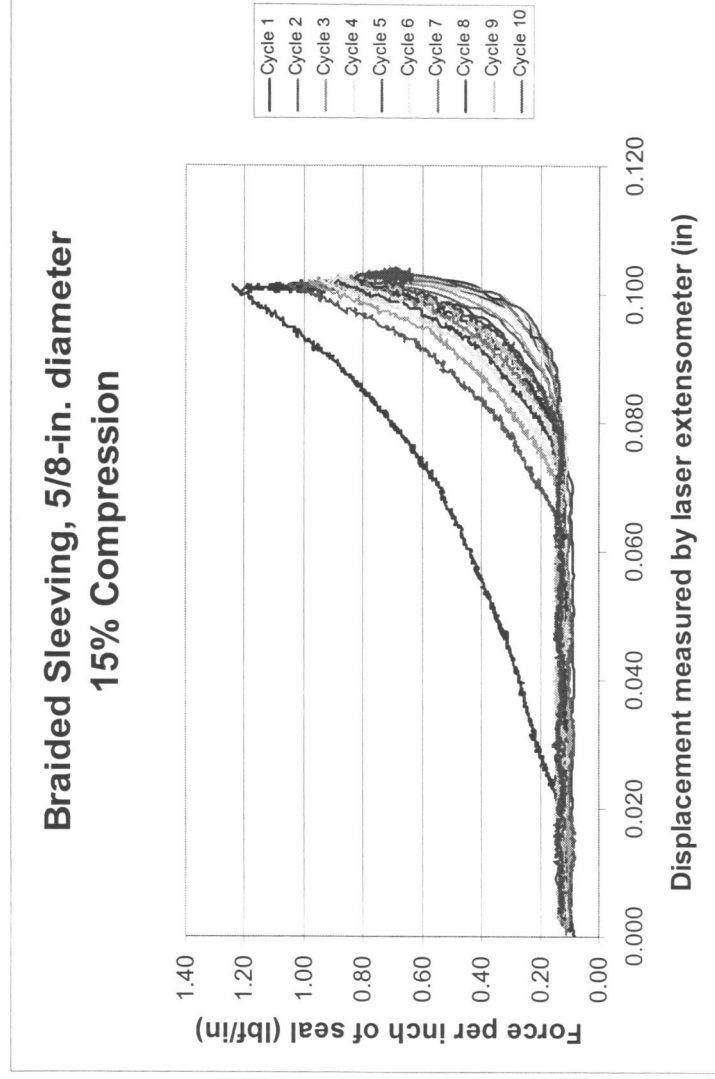
- Task agreement with Boeing to evaluate candidate TPS seal concepts for future Air Force space vehicles:
  - 1500 °F compression tests
  - Room temperature flow tests on seals before and after compression tests
- Phases 1 & 2: 40 tests completed
- Phase 3: additional tests on down-selected concepts in near future
- Tests helped check out facilities while providing useful data to customer



**Braided tape**



**Braided sleeving**



# Summary and Plans



- **Seal concept development**
  - Design and fabrication complete, 3Q FY03
- **Seal preloader development**
  - Award contract, 3Q FY03
  - Design and fabrication of initial seal preloader concepts, 1Q FY04
- **Test rig development & seal testing**
  - Hot compression rig
    - Test rig is operational
    - Perform hot compression tests on advanced seals in 3Q-4Q FY03
  - Hot scrub rig
    - Design and fabrication complete
    - Checkout complete and ready for tests, 3Q FY03
    - Perform hot scrub tests on advanced seals, 3Q-4Q FY03
  - Cold flow & scrub rig
    - Design and fabrication complete
    - Checkout complete and ready for tests, 3Q FY03
    - Perform cold flow & scrub tests on advanced seals, 4Q FY03
- **FY03 Milestone**
  - Complete critical function performance tests on first generation of advanced seals, 4Q FY03

